Emerging applications and science

ewa.kwiatkowska@eumetsat.int
Copernicus Sentinel-3A and -3B constellation is now operational

<table>
<thead>
<tr>
<th>OLCI-A, 1-day coverage</th>
<th>OLCI-A, 2-day coverage</th>
<th>OLCI-A, 3-day coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHL_OC4ME</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OLCI-A + OLCI-B, 1-day coverage</td>
<td>OLCI-A+OLCI-B, 2-day coverage</td>
<td>OLCI-A+OLCI-B, 3-day coverage</td>
</tr>
</tbody>
</table>
Sentinel-3 constellation status

- Sentinel-3A launched on 16 February 2016, in routine operation since October 2017

- Its twin Sentinel-3B launched on 25 April 2018, in routine operation since March 2019

- Sentinel-3A and -3B tandem phase between 6 June and 16 October 2018:
  - Sentinel-3B flying 30 seconds ahead of Sentinel-3A on the same ground track
  - Observation of similar Ocean and Atmosphere by both satellites
  - Extremely valuable data:
    - Analysing differences between the missions (biases, trends…)
    - Improving instrument calibration and characterization
    - Improving knowledge of measurement uncertainties

- Constellation final configuration reached on 27 November 2018 with Sentinel-3B placed in the same orbital plane as Sentinel-3A with a phase difference of 140°
  - OLCI revisit time better than three days (sun-glint free, daytime only)
S3A OLCI data availability

Main differences between PB v2.23 and PB v2.43
- Geometric calibration improvements
- No changes to L2 Ocean Colour processing, the only L2 changes are due to the L1B improvements
S3B OLCI data availability

- **L1B OPERATIONAL RELEASE**
  - PB v1.14 (12 Dec 2018)
  - PB v1.15 (20 March 2019)

- **L2 OPERATIONAL RELEASE**
  - PB v1.15 (20 March 2019)

- **L1B RELEASE TO S3VT**
  - PB v1.04 (25 Apr 2018)

- **L2 RELEASE TO S3VT**
  - PB v1.05 (28 Jun 2018)

- **L1B RELEASE**
  - EO portal.eumetsat.int
  - Data Centre: L1, L1 and L2
  - Coda.eumetsat.int
  - 1-year archive: L1, L1 and L2

- **EUMETCast**
  - NRT
Status of S3A products – water reflectance

Water Reflectance partly meets the 5% S3 Mission Uncertainty Requirement at averaged global and temporal scales

- Bands 490, 510, 560nm within 5% for all water types
- Bands 400, 412, 442nm within 5 - 10% depending on water type
- Other band uncertainties are higher and/or dependent on water type
- Product quality varies spatially and seasonally

Validations with AERONET-OC
Acknowledgement: JRC, NASA, AERONET-OC PIs
Results: Ilaria Cazzaniga

Inter-comparisons with MODIS-A and VIIRS
Acknowledgement: NASA
Results: Malcolm Taberner
OC4ME Open Water algorithm (Case 1) partly meets S3 Mission Uncertainty Requirements at averaged global and temporal scales

- Mesotrophic and eutrophic waters within 30%
- Oligotrophic waters underestimated by about 40%
- Product quality varies spatially and seasonally

Acknowledgement: NASA, SeaBASS PIs
Results: Ilaria Cazzaniga

Acknowledgement: NASA
Results: Malcolm Taberner

<table>
<thead>
<tr>
<th>SeaBASS</th>
<th>CHL_OC4ME</th>
<th>CHL</th>
<th>CHL_NN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>0.577</td>
<td>0.49</td>
<td>0.577</td>
</tr>
<tr>
<td>MAE</td>
<td>27</td>
<td>2</td>
<td>27</td>
</tr>
<tr>
<td>MAPE</td>
<td>75.82</td>
<td>75.82</td>
<td>75.82</td>
</tr>
</tbody>
</table>

Dec – Feb

Mar – May

Jun – Aug

Sep – Nov

SeaBASS #no MAE MAPE
CHL_OC4ME 25 0.577 25.49
CHL_NN 27 2.290 75.82

Oligotrophic waters

Mesotrophic waters

Eutrophic waters

OLCI-A MODISA VIIRS

UMETSAT
Status of S3B products – water reflectance

Water Reflectance does not meet the 5% S3 Mission Uncertainty Requirement – **OC-SVC is not available**

- Blue/green bands have positive bias within 7 – 20% compared to OLCI-A in oligotrophic and mesotrophic waters

Inter-comparisons OLCI-B with OLCI-A and MERIS Climatology

Acknowledgement: ESA, NASA for the Climatology

Results: François Montagner

Meso-/Eutrophic waters

Validations v1.05+v.1.15 with AERONET-OC

Acknowledgement: JRC, NASA, AERONET-OC PIs

Results: Ilaria Cazzaniga
Status of S3B products – algal pigment concentrations

OC4ME Open Water algorithm (Case 1) may partly meets S3 Mission Uncertainty Requirements at averaged global and temporal scales

- All water types may be within 30%
- However, no in situ ground-truth measurements are available to confirm
- Product quality varies spatially

Inter-comparisons OLCI-B with OLCI-A, MERIS Climatology and MODIS
Acknowledgement: ESA, NASA
Results: François Montagner

See Poster#12 by Ilaria Cazzaniga for OLCI in situ validations
## S3 OLCI L2 Ocean Colour product quality limitations

<table>
<thead>
<tr>
<th>Limitation</th>
<th>Ongoing/planned activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLCI-B water reflectance non-compliance</td>
<td>Recomputation of OC-SVC gains in second half 2019 when more OC-SVC matchups and the complete annual cycle of OLCI-B measurements are available</td>
</tr>
<tr>
<td>OLCI-A remaining water reflectance non-compliances</td>
<td><em>Idem</em></td>
</tr>
<tr>
<td>CHL_OC4ME oligotrophic chlorophyll underestimation</td>
<td>Algorithm update under implementation</td>
</tr>
<tr>
<td>Residual flag limitations</td>
<td>Short term: algorithm update, under implementation</td>
</tr>
<tr>
<td></td>
<td>Long term: revision of flags definition (QWG recommendation)</td>
</tr>
<tr>
<td>Residual angular/seasonal dependence varying with airmass</td>
<td>Investigations ongoing within the S3 Mission Performance Centre and QWG</td>
</tr>
<tr>
<td>‘Salt and pepper’ noise in Open Water products</td>
<td>Short term: algorithm update under implementation</td>
</tr>
<tr>
<td></td>
<td>Medium term: algorithm improvement, ongoing study</td>
</tr>
<tr>
<td>Reduced quality in coastal and complex-water areas (e.g. CDOM dominated),</td>
<td><em>Idem</em></td>
</tr>
<tr>
<td>recurring negative water reflectance</td>
<td></td>
</tr>
<tr>
<td>Complex Water NN algorithm (Case 2) limitations – variable quality, thresholds on product values</td>
<td>Algorithm update under implementation - altNN</td>
</tr>
<tr>
<td>Integrated water vapour biases</td>
<td>Medium term: algorithm improvement, ongoing study</td>
</tr>
<tr>
<td>L2 error products tentative (product_err)</td>
<td>Awaiting implementation of Level-1 error products, i.e. L1 per-pixel uncertainties</td>
</tr>
<tr>
<td>Consistent time series of products</td>
<td>Full-mission reprocessing of OLCI-A/B products planned in second half 2019</td>
</tr>
</tbody>
</table>
Ocean Colour data, from the Sentinel-3 Ocean and Land Colour Instrument (OLCI), provides a window into the ocean living ecosystems.

OLCI provides spectral information on the colour of the oceans. This data can be used to monitor global ocean primary production by phytoplankton, the basis of nearly all life in our seas.

Ocean colour data is also vital for Essential Climate Variables (ECVs) biological activity in the ocean during photosynthesis, making it possible to monitor the annual global cycle and study the impact of these on the ocean. Beyond climate, ocean colour can also be used to monitor coastal water quality, marine life, and even human activities such as agriculture and fisheries.

The full list of our ocean products can be found on our Ocean Products page.

**OCEAN COLOUR PRODUCTS**

The products are available in:
- Near-Real-Time (NRT): products shall be available to the users within three hours after sensing.
- Non-Time-Critical (NTC): products available to the users within one month after sensing.

The second table below lists the current operational OLCI products. Level 1 data provides ocean colour products derived from the top of the atmosphere signal. Level 2 products include the atmospherically corrected water leaving signal, as well as derived products including chlorophyll and total suspended matter estimates.

**DATE IN OPERATIONS**

<table>
<thead>
<tr>
<th>Product notices</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 March 2019</td>
</tr>
<tr>
<td>S3A: 2.43</td>
</tr>
<tr>
<td>S3B: 1.15</td>
</tr>
<tr>
<td>No update to L1 processing</td>
</tr>
</tbody>
</table>

| 12 Dec 2018       |
| S3A: 2.42         |
| S3B: 1.14         |
| + $3 Product Notice – OLCI |

| 14 Mar 2018       |
| 2.29              |
| Sentinel-3 Product Notice – OLCI Level-1B |

| L1 from 1 Oct     |
| 2.23              |
| Sentinel-3 Product Notice – OLCI Level-2 |

**Product Notices**

| Sentinel-3 Product Notice – OLCI Level-2 Ocean Colour |

**Mission**  Sentinel-3A & Sentinel-3B
**Sensor**  OLCI (A) & (B)
**Product**  Level 2 Ocean Colour
**OLCI/NRT**  OLCI Level-1 in NRT and NTC
**OLCI/NTC**  OLCI Level-2 in NRT and NTC
**Version**  1.0
**Preparation** This Product Notice was prepared by EUMETSAT with assistance from the Sentinel Mission Performance Centre

**Approval** EUMETSAT Mission Management

This Product Notice describes the status of the Processing Baselines (PBs) v2.63 (v3.30) and v3.63 (v3.30) available from the Marine Centre. The main update is related to the public release of OLCI Level-2 Ocean Colour products on 20 March 2019.

Both OLCI-A and OLCI-B Level 2 Ocean Colour processing is identical, except for the differences in application of System Level Calibration (SLC) calibration constants. For OLCI-A, SLC gains are applied. For OLCI-B, SLC gains are not applied.

For OLCI-A and OLCI-B, Level 2 Ocean Colour products are available for both v2.63 and v3.30 processing baselines. AllˮOcean Colour” products have been re-calculated using the new SLC constants.

This Product Notice provides product metadata and product quality information for both OLCI-A and OLCI-B. It also describes data access, product delivery, and the quality control process for Level 2 Ocean Colour products.

More information on the Sentinel-3 OLCI Level-2 Ocean Colour products can be found on EUMETCAST, including OLCI Level-2 Algorithm Theoretical Basis Documents, Sentinel-3A Ocean User Handbook, and other online product notices.

*Image: EUMETSAT*
• S3VT Annual meetings, active participation, excellent feedback
• S3VT-OC Monthly teleconferences
• S3VT meeting 7-9 May 2019 at ESA ESRIN in Frascati, Italy
  • Day-1 09:00 – 13:00 Plenary; 14:00 – 17:00 joint Optical session OLCI/SLSTR/calibration, 17:00 – 18:30 Posters
  • Day-2 09:00 – 17:00 parallel sessions (Ocean Colour), 17:00 – 18:30 Posters
  • Day-3 09:00 – 12:00 parallel sessions (Ocean Colour), 13:00 – 15:00 Plenary
EUMETSAT has been cooperating with ESA, EC-JRC and international space agencies on activities towards establishing Copernicus OC-SVC capability

- ESA organized an international Workshop on Vicarious Infrastructure in the frame of the FRM4SOC project (report available and final workshop material)
- EC-JRC published a series of peer-reviewed scientific papers and a JRC technical report (report available)
- EUMETSAT developed “Requirements for Copernicus Ocean Colour Vicarious Calibration Infrastructure” with inputs from an international expert review team
- EUMETSAT Copernicus initiated “Preliminary Design of the Copernicus Ocean Colour Vicarious Calibration Project: Infrastructure, Project Planning and Costing”

Copernicus OC-SVC Roadmap

1. Requirements
2. Preliminary Design, Project Plan and Costing
3. Engineering Design, Technical Definition, Specifications
4. Development, Testing and Demonstration in the Field
5. Operations
Two parallel candidate OC-SVC Preliminary Designs: based on the optical system design of MOBY

Step-1 OC-SVC Requirements

Step-2 Preliminary Design of the Copernicus OC-SVC infrastructure, planning and costing

- In-water spectrophotometers
- MOBY-design optical system
- Ancillary instruments and HW
- Independent buoys design
- Site selection and characterization
Two parallel candidate OC-SVC Preliminary Designs: based on the field design of BOUSSOLE

Step-2 Preliminary Design of the Copernicus OC-SVC infrastructure, planning and costing

Field Segment: deploying gears and delivering data
- Two candidate field sites
  - Ligurian Sea
  - Cretan Sea ("Mega")
- Float network + Option for growth
  - PROVAL
  - "EIO"
  - Extension of the ROSACE footprint
  - Extension to southern hemisphere conditions, Australia Copernicus data hub
  - LOV, IMEV, BGC, ANU

Ground Segment: field data processing and quality control
- Centralised field data processing (e.g., Radiance normalisation & BRDF, satellite SRF integration, auxiliary data) and archiving
- Data quality control (DQ)
- Data access from raw data to final Quality-controlled marine radiances and reflectances
- Field data re-analyses
- Environmental and processing chain uncertainties

Uncertainty budget (NMI role)
- Uncertainties to be associated to the delivered data
- Field data, environmental and data processing uncertainties

Support - Leadership, missions, and international bodies (OC-ESI OCT-VG)
IOCS recommendations advances in Atmospheric Correction, NIR modelling

**Objective:** develop an improved correction for non-negligible water reflectance in the NIR for OLCI

**Schedule:** June 2018 – June 2019

---

**OC-BPC**

*Ocean Colour Bright Pixel Correction*

Review of OC-BPC approaches to facilitate the NIR-based clear water Atmospheric Correction

- Marine modelling in the NIR: IOPs and BRDF reflectance model
- Numerical inversion: spectral optimization method with configurable bands
- Uncertainty formalism: per-pixel radiometric and model uncertainties
- Analysis of ambiguities in the water/atmosphere decoupling
- Modular processing code

Integration of community’s recent advancements in Atmospheric Correction over complex waters

Validation and analysis of the improvements using in-situ measurements, selected scenes and time series

International Expert Team is gratefully acknowledged for exceptionally valuable support to this study

See Breakout workshop #9 and the next S3VT meeting 7-9 May 2019
**IOCS recommendations**

**advances in aerosol Atmospheric Correction**

**SACSO**

*Spectral matching Atmospheric Correction for Sentinel Ocean colour measurements*

**Objective:** develop an *improved aerosol atmospheric correction*, with application to OLCI and other sensors

**Schedule:** March 2019 - August 2020

---

**Spectral matching approach based on Polymer**

- Generic and accurate in oceanic and coastal waters
- Using a wide range of spectral bands for atmospheric correction allows for an enhanced precision, especially in the shortest wavelengths
- Robust to aerosols (including absorbing ones) and other atmospheric and surface effects: sun glint, thin clouds, adjacency effects

**Scientific tests and developments to improve and consolidate the algorithm**

- Review the atmospheric and surface model. In particular, account for the aerosol transmittance
- Review the water reflectance model
- Review the optimization scheme: improve algorithm stability over oligotrophic waters
- Develop an uncertainty propagation scheme
- Optimize the choice of spectral bands

**Validation and analysis of the improvements**

- Using simulated and in-situ data
- Integration of the aerosol AC module in a multi-mission Ocean Colour prototype
IOCS recommendations
advances in IOP inversion in oceanic and inland waters

IOP
IOP inversion in natural oceanic and inland surface waters

A two steps approach selected:
- Different algorithms were tested to estimate $a_{\text{phyt}}$, $a_{\text{cdom}}$, $b_{bp}$, and $a_{\text{cdom}}$
- Algorithm is coupled with a water type classification

Algorithm has been validated over open, coastal, and inland waters based on in situ $R_{rs}$ and IOPs measurements, as well as using match-up data points

Uncertainties are provided for each IOP based on a class based approach

International Expert Team is gratefully acknowledged for exceptionally valuable support to this study

Objective: develop IOPs for OLCI
Schedule: Jan 2018 - May 2019

$R_{rs}$, IOPs

matchups (GlobColour $R_{rs}$, in situ IOPs)

$\lambda = 444$

$log(y) = -0.22 + 0.92 \log(x)\quad R^2 = 0.88\quad N=1145(100\%)$

$log(y) = 0.35 + 1.11 \log(x)\quad R^2 = 0.95\quad N=11202(99.95\%)$

$log(y) = 0.01 + 0.10 \log(x)\quad R^2 = 0.91\quad N=1290(100\%)$

$log(y) = 0.28 + 1.20 \log(x)\quad R^2 = 0.84\quad N=4029(91\%)$

$log(y) = -0.43 + 0.03 \log(x)\quad R^2 = 0.74\quad N=724(90\%)$

$log(y) = 0.01 + 0.82 \log(x)\quad R^2 = 0.74\quad N=540(91\%)$

$log(y) = 0.01 + 0.92 \log(x)\quad R^2 = 0.74\quad N=540(91\%)$

$log(y) = 0.01 + 0.82 \log(x)\quad R^2 = 0.74\quad N=540(91\%)$

$log(y) = 0.44 + 1.20 \log(x)\quad R^2 = 0.84\quad N=4029(91\%)$

$\lambda = 444$

$log(y) = 0.28 + 1.20 \log(x)\quad R^2 = 0.84\quad N=4029(91\%)$

$\lambda = 444$

$log(y) = -0.43 + 0.03 \log(x)\quad R^2 = 0.74\quad N=724(90\%)$

$log(y) = 0.01 + 0.82 \log(x)\quad R^2 = 0.74\quad N=540(91\%)$

$log(y) = 0.28 + 1.20 \log(x)\quad R^2 = 0.84\quad N=4029(91\%)$
IOCS recommendations
advances in phytoplankton fluorescence retrievals

Fluorescence
Phytoplankton physiology

Objective: develop fluorescence product for OLCI

Schedule: Sep 2018 – Sep 2019

Validation and analysis of product quality

Review of user requirements, state-of-the-art and OLCI capabilities for fluorescence detection

Two parallel developments of fluorescence from the L1 TOA radiance and from L2 water reflectance
IOCS recommendations
benefits of geostationary Ocean Colour capabilities

1. Significant improvement in coverage
- Increased chance of obtaining cloud-free data compared to standard polar observations, data free of gaps between orbits
- Bay of Biscay daily coverage from a geostationary and a polar mission showing a coccolithophore bloom: major process for long-term carbon burial in the oceans

2. Monitoring of dynamic processes
- Tidal dynamics, eddies, fronts, sediment transport, coastal erosion, river plumes, natural and anthropogenic disasters

References
- Pioneering Geostationary Ocean Colour Imager (GOCI) from KIOST, since 2010
- Copernicus Marine Environment Monitoring Service (CMEMS) requirements for the evolution of the Copernicus Satellite Component, 2017
- International Ocean Colour Coordinating Group, IOCCG report #12, edited by Antoine, 2012

[Neukermans et al., 2012; Neukermans, 2012]
Demonstration of GEO MSG water turbidity monitoring and MTG feasibility for chlorophyll retrievals

Completed GEO activities User Requirements

MSG SEVIRI prototype processor and validation

<table>
<thead>
<tr>
<th>User Applications</th>
<th>Parameter</th>
<th>Best Spatial Resolution</th>
<th>Temporal Resolution</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal water quality (EU MSFD)</td>
<td>TUR, SPM, SD</td>
<td>300m-1km</td>
<td>1h - 10y+</td>
<td>threshold</td>
</tr>
<tr>
<td>Water quality of European lakes (EU WFD)</td>
<td>TUR, SD, XCYA</td>
<td>300m-1km</td>
<td>1h - 10y+</td>
<td>threshold</td>
</tr>
<tr>
<td>Coastal water quality - Africa</td>
<td>TUR, SD, XHAB</td>
<td>~1km</td>
<td>1h - 10y+, NRT</td>
<td>scientifically sound</td>
</tr>
<tr>
<td>Water quality of African lakes</td>
<td>TUR, SD, XCYA</td>
<td>300m-1km</td>
<td>1h - 10y+</td>
<td>scientifically sound</td>
</tr>
<tr>
<td>Sediment transport</td>
<td>TUR, SPM</td>
<td>10m-1km</td>
<td>1h - 10y+</td>
<td>absolute</td>
</tr>
<tr>
<td>Ecosystem modelling (eutrophication)</td>
<td>KdPAR/2E, SPM</td>
<td>1-10km</td>
<td>1h - 10y+, some NRT</td>
<td>uncertainty per pixel</td>
</tr>
<tr>
<td>Offshore diving operations</td>
<td>TUR (HVS)</td>
<td>1-100m?</td>
<td>10m - 6h, NRT</td>
<td>scientifically sound</td>
</tr>
<tr>
<td>Carbon burial by coccolithophores</td>
<td>CDOCO</td>
<td>~10km</td>
<td>1h - 10y+</td>
<td>unknown</td>
</tr>
<tr>
<td>Support for OC validation</td>
<td>Rrs</td>
<td>300m-1km</td>
<td>5m - 10y+</td>
<td>absolute</td>
</tr>
</tbody>
</table>

Upcoming development

Multi-year MSG SEVIRI water turbidity time series

MTG FCI feasibility study of additional OC products, like chlorophyll, $a_{ph440}$, $a_{cdm440}$, $K_{dA}$
Sentinel-3A and -3B OLCI constellation is now operational!
OLCI product improvements ongoing
Copernicus OC-SVC roadmap activities in step 2
‘preliminary design’
Scientific studies in progress on algorithm evolution and new products
Activities follow IOCS recommendations and harness international expertise